A · G · A · V · E

Quarterly Magazine of the Desert Botanical Garden, Phoenix, Arizona

FALL 1986

ISSN 0735-0652

A·G·A·V·E
VOLUME 2, NUMBER 2 / FALL 1986

COVER: Thornber's Fishhook Cactus *(Mammillaria thornberi).* Photo by George H. Huey/Arizona Highways

INTRODUCTION

by Robert G. Breunig, Ph.D.
Executive Director, Desert Botanical Garden

The Quiet Crisis

In November 1985 a group of botanists and botanical garden administrators from all over the world met in the Canary Islands to assess the state of the world's flora. Dr. Peter Raven, of the Missouri Botanical Garden, delivered a paper which came to the startling conclusion that if present trends continue, by the middle of the next century destructive human activity may result in the extinction of 60,000 plant species in the tropical and subtropical parts of the world alone. *This figure represents nearly one quarter of the earth's higher plant species.* Thus, the next sixty years could turn out to be one of the great epoch's of plant extinction in all of the earth's history.

A threat on a similar scale faces the flora of the temperate, arid, and semi-arid regions of the world. In the United States, for example, roughly 15% of the native flora are threatened with extinction. The percentages are even higher in arid regions where large scale agricultural projects, urban development, mining, livestock grazing, fuelwood harvesting, unscrupulous specimen collecting and unrestrained recreational activities are all radically disturbing fragile desert ecosystems. These threats to the flora of arid and semi-arid lands are causes for much concern.

As Dr. Gary Nabhan points out, while the sheer number of species in the tropics exceeds those of the deserts, arid region plants employ a wider range of survival strategies and employ a greater diversity of life forms than do tropical plants. The wholesale loss of arid-adapted species will, therefore, have a serious impact on the genetic richness of the world.

No matter what region plants are from, the projected degree of global plant extinction will have enormous ecological consequences. Plants form the foundation of the earth's food chain. Many animals have co-evolved with specific plants and are totally dependent upon them. Harold Koopowitz has estimated that for every plant species that becomes extinct, as many as eleven animal species may follow.

Thus the loss of plant diversity will reverberate through the food chain and dramatically affect the diversity of *all* life forms. Widespread plant destruction will also affect atmospheric temperatures and rainfall patterns resulting in modifications to global climatic conditions and weather patterns. Indeed, this has already happened to a certain extent. It is now believed that the recent pattern of chronic drought in north central Africa may have been triggered by plant destruction through livestock overgrazing and fuelwood cutting.

Maintaining plant diversity is also important for agriculture and medicine. Our modern system of mechanized agriculture which emphasizes large, genetically uniform crops, has proved to be dangerously vulnerable to blights. For example, in 1970, a corn blight in the United States destroyed 15% of the crop. The genetic diversity found in the wild relatives of our domesticated crops has contributed to the maintenance of healthy plant breeding stock. In addition, plants which are constantly being fed upon by insects and other animals have evolved complex chemical defense mechanisms. These chemical properties are often discovered to have medicinal benefits for humans. While some scientists have properly cautioned against expecting to find "miracle cures" in all endangered species, the fact remains that about one quarter of the medicines we use today are from plant derivatives.

Statistics on the rate of worldwide plant extinction such as those presented at the Canary Island conference are forcing botanical gardens to examine their roles in the urgent need for plant conservation. It is recognized that unless we take positive actions soon and become actively involved in this "quiet crisis," we shall leave a world with a much improverished flora to future generations.

The fact that we have not named, classified, studied or perhaps even discovered vast portions of the world's flora which are now threatened means that we and our descendents could forever forfeit any potential benefits these plants may offer humankind.

Defining Strategies

If we accept the proposition that a respons-

ible plant conservation program should be a central component of every serious botanical garden, then we must define various institutional strategies.

There are two fundamental approaches to the problem of plant conservation. The first and ideal conservation technique is what is called *in situ* conservation, or preservation of a plant in "its original place" — its natural habitat. To preserve the world's flora *in situ,* everything possible should be done to set aside reserves, free of development, designed to preserve the diversity of the earth's plant material. These reserves must be located in a wide variety of ecological niches worldwide and must be of sufficient size to permit viable ecological interactions. Unfortunately, of the many parks and reserves that have already been established throughout the world, many are too limited in size or are not currently managed to adequately preserve biological diversity. It has been demonstrated that if a preserve is set up which is too small (the optimal size will depend upon the type of ecosystem), and if the land around the preserve is subsequently degraded, then the number of species within the preserve — which is only an "island" of undisturbed land — will decline. The disrupted ecology within the "island" cannot maintain the number of species that could live on that very same piece of land when it was part of a larger, intact, biological community. This species decline will continue until a new equilibrium is reached within the preserved area. For example, it has been estimated that to preserve most of the species in the tropical rainforests of the Amazon, approximately 20% of the remaining forest would have to be put into reserve status. To date Brazil, which controls much of Amazonia, has set aside only 3% of its land as preserve. Therein lies the fundamental shortcoming of the *in situ* preserve approach. The political willingness simply does not exist in most countries in the world today to set aside enough preserve land to guarantee adequate protection of plant species in the wild. This reality has led botanists to reluctantly fall back on the second approach.

Where adequate habitat preservation is not possible, this supplementary strategy, called *ex situ* conservation, must be tried. This involves bringing germplasm of threatened plants into botanical gardens for long term conservation. It should be immediately acknowledged that there are serious limitations with this approach. First, the number of species to be preserved worldwide is enormous — far beyond the capacity of the world's estimated 500 botanical gardens to cope with adequately. Second, these gardens will be attempting to maintain sensitive wild plant populations in an inherently unnatural situation. It is often difficult to replicate within botanical gardens the growing conditions and complex interactions which exist for rare plants in the wild. Finally, assuming that a species can be maintained in a botanical garden, there must also be an adequate number of individuals of each species so that there is enough genetic variability to maintain a healthy gene pool for the plant. It is now believed that, in most cases, a garden must maintain a minimum of fifty plants *per species* in the collection. Multiply that number by very many species and it is easy to see that the garden is taking on a major commitment of space, staff time and financial resources to support a collection of threatened plants. In addition to maintaining and propagating live plants on their grounds, botanical gardens are also setting up seed banks for maintaining the long term viability of seeds of endangered plants. Despite the limitations of *ex situ* conservation, it is essential that it be done. For many plants, there is no alternative. The Desert Botanical Garden must become more involved in both *in situ* and *ex situ* plant conservation efforts.

Patrick Quirk in the propagation greenhouse at the Desert Botanical Garden. Photo by George H. Huey/Arizona Highways

In the domain of *in situ* conservation, we can contribute by doing fundamental taxonomic and ecological field research on rare and endangered desert plants. This research must be directed at basic fundamental questions such as: Which plants are endangered? Where are they located? How do they interact with their environment and with other organisms? What is their taxonomic status? How can their habitats be protected? What must be done to insure their survival as a species? Armed with good data based on these kinds of questions, we can begin to make reasonable recommendations to land managers and public policy makers on how plant habitats can be managed to preserve species diversity. Such research can also assist private conservation organizations, such as The Nature Conservancy, in its efforts to purchase lands for species protection.

Today, the Desert Botanical Garden is working with various state and federal agencies on this type of basic research. The articles by Dr. Nabhan and Ms. Hodgson on the study of *Toumeya papyracantha* and *Agave arizonica* for the U.S. Office of Endangered Species are but two examples of such research.

The long-term effort for increased protection of plant habitats will not come soon enough, however, for some species which are now threatened with imminent extinction. If these species are to survive at all, some of their remaining population must be brought to the protected environment of the botanical garden. This must be done despite the problems and risks of *ex situ* conservation cited above.

In 1985 the Desert Botanical Garden took its first major step into the realm of *ex situ* conservation when it joined the Center for Plant Conservation. By banding together, this consortium of eighteen botanical gardens nationwide has established a national collection of rare and endangered plants of the United States. The Center, which is headquartered at Harvard University's Arnold Arboretum, coordinates the first nationally coherent program of *ex situ* plant conservation. Each of the eighteen gardens takes responsibility for the plants of a particular geographic region. The Desert Botanical Garden is covering the plants of the Sonoran and Chihuahuan Deserts north of Mexico. Every year, botanists from each of the eighteen institutions select the plants from their own region that they believe are under severe threat and whose population should have a sample collection removed from the wild for permanent care and propagation within the botanical garden. There is a specific set of criteria for determining which plants these are. Imminence of extinction in the wild, and the feasibility of long-term *ex situ* conservation are two of the major criteria. The list is reviewed by a nationally distinguished group

INTRODUCTION

of botanists. Once approved, and after the necessary federal or state permits are obtained, the Center for Plant Conservation provides funds for the field recovery of these sample populations. The number of individual plants recovered depends upon the total population existing in the wild, but again, a minimum of fifty individuals is considered desirable. The plants are brought to the garden for protected care and propagation. For this care the Center for Plant Conservation also provides an additional annual endownment for each species. If all goes well, and the population is stabilized and increased through each garden's plant propagation program, individuals from the new populations will be offered to other regional botanical gardens so that the germplasm is distributed to a variety of locations. Hopefully, some of these plants can also be returned to the wild in the future when it is presumed that more enlightened land management practices will create conditions more favorable to their survival. To date, the Desert Botanical Garden's work through the Center for Plant Conservation has recovered samples of 24 species and plans have been approved to recover 10 more species in the coming year. The article in this issue on the recovery of *Mammillaria thornberi* is an example of this *ex situ* conservation program at work.

A Long-term Commitment

It is important for the public to realize that these kinds of programs represent serious, long-term commitments by botanical gardens. Once a rare plant is brought into an institution for permanent care, the garden has an obligation to maintain that care regardless of changes in staff or administration. The board of trustees and the management of the garden must take steps to insulate the endangered plant collection from shifting priorities or the whims of a particular director. The institution must also engage in research designed to help the horticulturists and propagators better manage and increase these collections.

The Desert Botanical Garden considers its work in plant conservation to be an almost sacred obligation, and we expect to expand our program in the next few years. The need to do this is urgent. We cannot wait much longer. In our view, nothing could be more important than working to preserve the diverse desert flora that exists today. If we fail at this fundamental task we will have failed future generations — and we will leave them with a much poorer world. ■

by Gary Nabhan, Victor Gass, and Patrick Quirk

Thornber's Fishhook Cactus: CONSERVING A

Threatened and endangered species: do we tend to stereotype the organisms that we lump into these categories? Do we visualize the delicate orchid known only from one spring-fed marsh, or the aberrant succulent encountered in just a few rugged canyons? And is it assumed that the way to conserve them is a straightforward process? Can we simply set aside their habitat as a conservancy area or national park, and bring a few seeds into cultivation in a botanical garden?

Thornber's fishhook cactus *(Mammillaria thornberi)* is a Sonoran Desert endemic plant that makes these stereotypes crumble. It forces us to rethink the conservation process. Scattered over 4,000 square miles centered on Pima County in Arizona, it prefers the broad desert basins to canyons or other special environments. Yet the core of its range west of Tucson has been increasingly converted to irrigated farms, trailer parks, and suburban ranchettes over the last half century. Even in one of the two National Parks where this cactus does occur, its populations have apparently been declining. And in the past, the few *M. thornberi* clumps transplanted to botanical gardens and outdoor museums have not persisted, dying out after a while due to unknown causes.

Recently, the Central Arizona Project aqueduct to Tucson has begun cutting through the densest populations of this species known to scientists. Although proposed as a threatened plant species in 1983 when less than 600 plants were known, the Thornber's fishhook cactus failed to receive official status as a nationally threatened plant this year because Bureau of Reclamation surveys found it to be much more abundant than had previously been thought. Ironically, many of the newly-found populations are precisely those which will have to be salvaged and removed from their habitat before it is destroyed by the aqueduct. Currently, its status is in limbo. Outright collecting of it (and other cacti) is restricted by state laws, but federal protection of the species has been postponed. It is listed as a federal *category 2* species.

To deal with this complex situation, the Desert Botanical Garden has joined the several institutions and agencies assessing this species' status, and we are refining strategies for its protection. We offer an integrated approach which includes four activities:

1. When plants need to be salvaged because their habitat is destined for destruction, we attempt to document as much about their on-site ecological relationships as possible before transplanting them.
2. Once brought into cultivation, we study the best ways to propagate them for long-term maintenance of population variability and for later reintroduction into the wild.
3. Concerning remaining natural populations, we evaluate the threats facing them and the rate of loss that can be expected unless additional measures for protection are taken.
4. We disseminate this information to pertinent agencies and conservation groups, thus serving as an advocate for further conservation efforts when appropriate.

Mammillaria thornberi

Plant salvage in the Avra Valley of Arizona.

DECLINING SPECIES

The following is a summary of our current and proposed activities in each of these areas.

Documentation of Thornber's Fishhook Cactus Ecology On Site

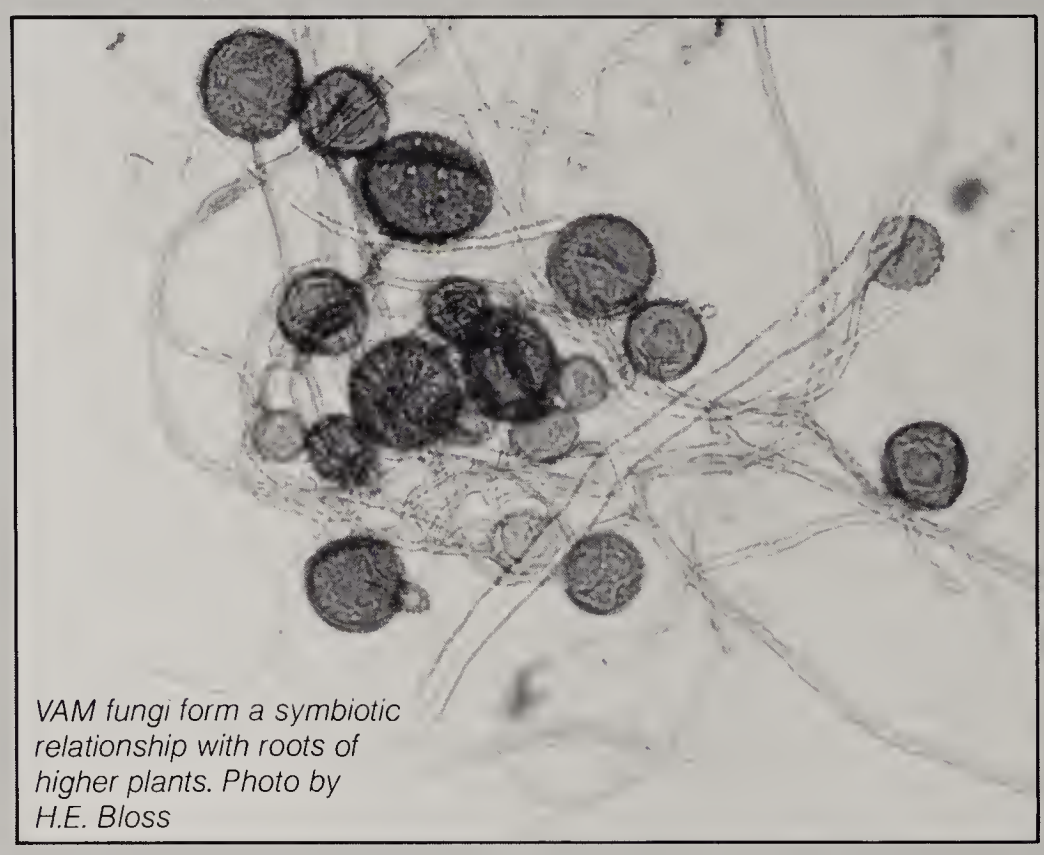
Too often, plant salvages are accomplished without any information being taken in the field on the ecology of the plants to be removed. For example, in some cases, there now exist species of plants in botanical gardens, but we know virtually nothing about their ecological context in the wild. To remedy this situation, Desert Botanical Garden staff and volunteers collected considerable data, along with plants, during April and August 1986 salvages for *Mammillaria thornberi* in Avra Valley, Arizona.

Our first question was: how dependent are Thornber's fishhook clumps on protection by particular (overstory) nurse plants, relative to the overall composition of the vegetation where they grow? *Table 1* (top right, page 7) presents the percent of fishhook clumps found in various settings during the two salvages.

From *Table 1*, it is clear that few if any fishhooks are established on open ground at the two sites, even though vegetation covers only 12% and 18% of the ground area at these sites, as line transect data indicates. More than 80% of the fishhook clusters that we recorded in Avra Valley are found in the protective shadow of either creosote bush or triangle-leaved bursage. In the past, ecologists have suggested that protective cover may serve to buffer fishhook clusters from hot and cold temperature extremes, from trampling by cattle or big game, or from consumption by rodents and rabbits.

But does Thornber's fishhook cactus have a better chance of surviving under a *particular* nurse plant? In other words, are they non-randomly dispersed and established under these two shrubs in particular? Ecologist Joe McAuliffe (1984) of the University of Arizona has discovered such a non-random distribution of *Mammillaria microcarpa* at Organ Pipe Cactus National Monument, where they tend to survive to a greater extent under the jumping cholla, *Opuntia fulgida,* than under more common components of the vegetation.

At both sites in Avra Valley, there is a tendency for more *Mammillaria* to survive under creosote bush relative to its overall contribution to vegetative cover. Although our line transect data shows that creosote contributes only 38% of the plant cover on the first site, more than 54% of the fishhook clumps are found under one of these shrubs. Thus over half the plants of this rare cactus are associated with a shrub that covers less than 5% of the site's ground area. At the second site, creosote comprised only 24% of the vegetative cover, but again, almost half the cactus clusters were found in their shadows. Relative to the more dominant bursage, creosote serves as a nurse plant for *Mammillaria thornberi* more frequently than would be expected on the basis of our line transect data.



VAM fungi form a symbiotic relationship with roots of higher plants. Photo by H.E. Bloss

Why do we find so many fishhook clumps under creosote? Do birds which nest or perch in this shrub differentially disperse more of *M. thornberi's* bright red fruit to these shadows than to other microsites? Are cactus seedlings more protected from killing freezes or hundred degree days under creosote than under bursage or in the open? Are they less likely to be trampled or eaten? Research on the transplanted fishhook clusters may offer us a fresh look at this matter. It may also help us determine the critical factors for fishhook survival in the wild, should we attempt to reintroduce progeny of our salvaged plants into the wild at some future date.

Propagation for Long-term Maintenance

Since previous surveys had noted that *M. thornberi* is most abundant on sandy loam soils derived from granite (Rutman, 1985), we became concerned about the soil ecology of our salvaged plants. Both the Garden and the Arizona-Sonora Desert Museum had transplanted Thornber's fishhook populations which eventually died out. Could inappropriate soil substrate have been a possible factor? We decided to design a set of analyses and experiments to better determine the most suitable soil media for sustaining fishhook clusters.

To begin with, DBG staff took roots of this cactus and associated soil to the laboratory of Dr. H.E. Bloss at the University of Arizona, to learn of the microflora known as VAM fungi that form a symbiotic relation with roots of higher plants. These root-penetrating fungi benefit cacti and certain other desert plants by improving their capacity to absorb minerals essential to plant establishment, growth, and reproduction (Bloss, 1985a).

By staining the cactus roots with a dye and observing filaments and spores of fungi (Figure 1), Dr. Bloss confirmed that VAM fungi were associated with *Mammillaria thornberi* from Avra Valley. Bloss (1985a) had earlier observed that VAM fungi are also associated with creosote from the Tucson Mountains outskirts, but these microflora are commonly absent from the wide, barren interspaces between desert plants, as well as from soils from highly disturbed areas! It has been suggested that where VAM fungi are absent, higher plants which normally benefit from their association may fail to become established or to persist. Where an older nurse plant has VAM fungi already on its roots, these fungi may be transferred to the new roots of a seedling that grows up next to it. Could such a phenomenon account for the high association of fishhook clusters under creosote bushes which we observed in the field?

To test this hypothesis and to help us better establish Thornber's fishhook clusters in the Garden, we have designed experiments which situate them in various soil media, with or without VAM fungi added. From samples of three soil treatments which Desert Botanical Garden staff provided from these cactus propagation experiments, Dr. Bloss observed the following microfloral conditions: Desert valley surface strata from around *Mammillaria* clumps in Avra Valley contained more than 20

spores per gram of soil of two species of *Glomus,* or VAM fungi; soil taken from a mildly-disturbed area on the edge of the Desert Botanical Garden propagation facilities contained only one *Glomus* species, with less than 10 spores per gram of soil; our "DBG Cactus Mix," consisting of pumice, sphagnum peat, Greenworld compost and sand, contained no fungal spores or hyphae.

Developing Favorable Soil Conditions

In mid-April, we set up a propagation experiment to determine if differences in soil media used for potted cactus would affect the long-term reproduction and survival of Thornber's fishhook cactus. On a monthly basis, we are monitoring the size classes and numbers of cactus heads per cluster of *M. thornberi* transplanted into three soil media: 1) 100% DBG Cactus Mix; 2) 100% silty soil from DBG grounds; and 3) 50% DBG Cactus Mix and 50% Avra Valley soil from the original habitat of the plants. We are measuring the growth and mortality of cacti potted in five pots each of three sizes within each of these three soil treatments. The preliminary results from the first five months of this study still in progress are graphed in Figure 2.

We are also weighing the fruit bulked from cacti in each treatment on a monthly basis. Our immediate observations are that vegetative and sexual reproductive rates may be somewhat slower for the cacti in the heavier soil from DBG rounds. Differences between the other two treatments are not yet dramatic. As time passes, we expect the performances of these two treatments to diverge.

Following the proposal of Bloss (1985b), we are also attempting to see if fishhook transplants into pots and onto our grounds benefit from being inoculated with a mix of *Glomus* fungi prepared in the laboratory. (This technique is now being evaluated by nurserymen working with a variety of ornamental plants.) We are also comparing the growth and survival rates of inoculated versus noninoculated *Mammillaria* placed out on our grounds beneath creosote bushes. The growth of smaller, bare-rooted *Mammillaria,* inoculated at the time of potting, is also being monitored. Through this set of complementary experiments, we hope to establish the most favorable combination of soils, site placement, and micro-organisms which can help maintain fishhook cacti populations on our grounds indefinitely.

Table 1: Percent of *M. thornberi* found in various ecological contexts during Avra Valley salvages by DBG in 1986.

Location	% in April salvage		% in August salvage	
	Sole cover	*Mixed*	*Sole cover*	*Mixed*
On open ground	0	—	0	—
Under:				
Creosote bush	58%	23%	42%	18%
Triangle-lvd. bursage	39%	47%	39%	26%
Prickly pear	0	0	0	3%
Cholla cactus	0	23%	7%	18%
Galleta grass	0	0	0	5%
Little leaf palo verde	0	0	8%	24%
Mesquite	3%	3%	1%	3%
Whitethorn acacia	0	3%	0	0
Ironwood	0	0	1%	3%
Barrel cactus	0	0	2%	0
Total No. of clumps	38 (100%)	15 (100%)	165 (100%)	19 (100%)

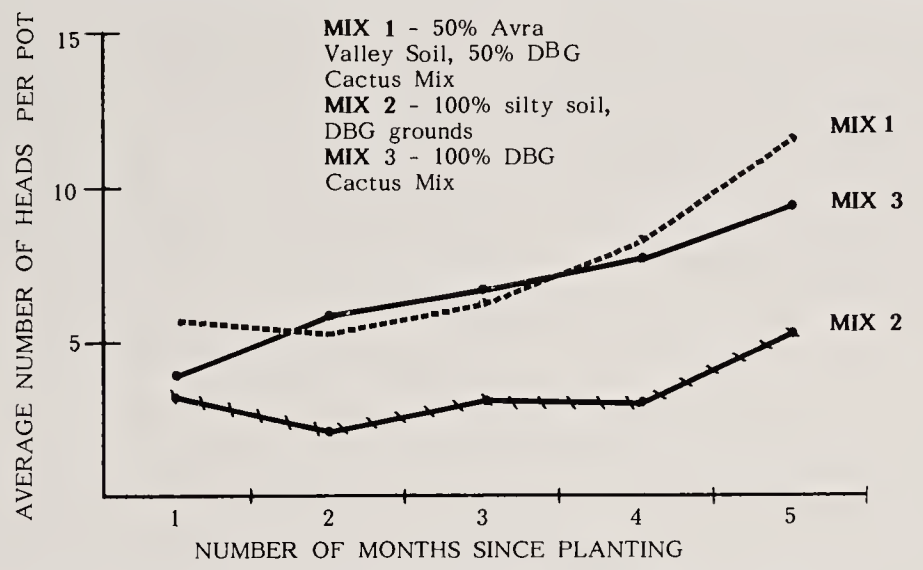


FIGURE 1. Survival and increase of heads of Mammillaria thornberi in small pots filled with different soils.

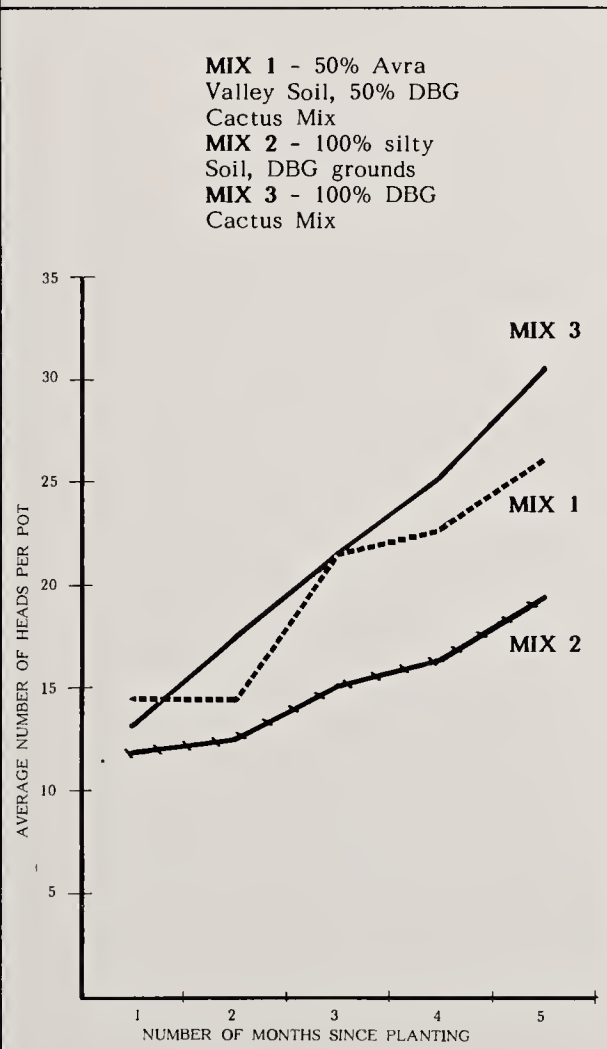


FIGURE 2. Survival and increase of heads of Mammillaria thornberi in small pots filled with different soils.

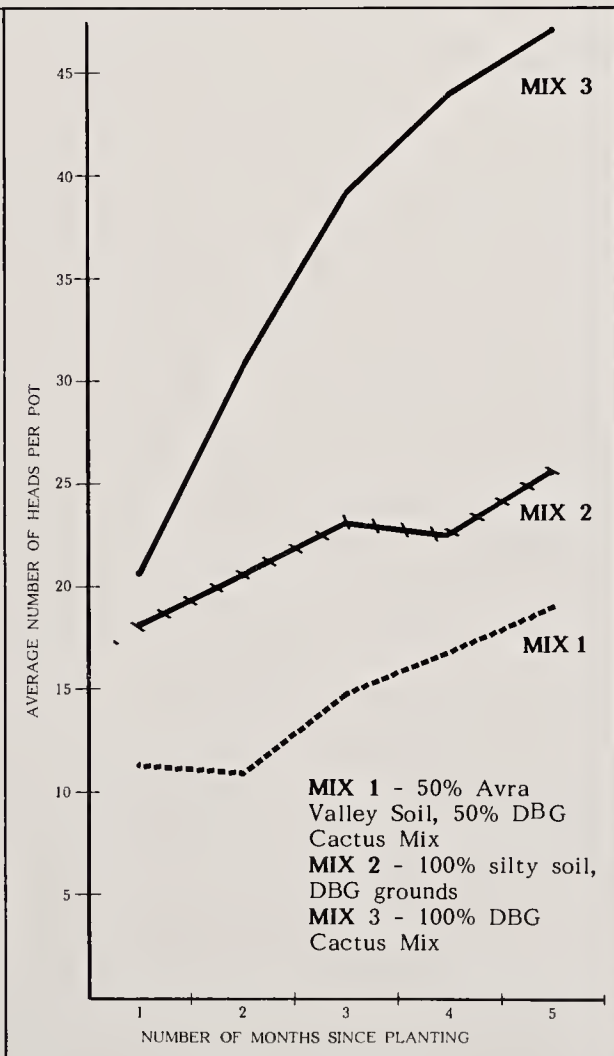


FIGURE 3. Survival and increase of heads of Mammillaria thornberi in small pots filled with different soils.

Garden staffers Victor Gass and Tom Ahlstrom on a salvage project.

Evaluating Threats to Remaining Natural Populations

The Office of Endangered Species of the U.S. Fish and Wildlife Service has tentatively identified nine threats to *Mammillaria thornberi* in the wild, six of which directly or indirectly relate to land use change within its range. Agricultural development and urban expansion are among those threats which result in conversion of wildlands habitat in such a way that the fishhook clumps and their nurse plants are eliminated.

Unfortunately, no one knows if the land uses changing prime *Mammillaria* habitat are affecting enough of it to threaten the long-term survival of the species. In order to develop an objective method of assessing the effects of land use change on any potentially threatened species, the Desert Botanical Garden staff has proposed an analysis of historic aerial photos of Avra Valley in conjunction with the Applied Remote Sensing Program of Dr. Michael Parton and Dr. Charles Hutchinson at the University of Arizona. We will planimeter the areas on photos showing where wildlands have been converted to agricultural and urban uses during several periods from the 1930s to the present. By comparing the amount of wild habitat within the range of Thornber's fishhook on photos from 1936 with those from 1961, 1974, 1984 and 1987, we will quantify how much habitat has likely been lost already, and evaluate to what extent the rate of change has been accelerating. Recommended for funding by the National Park Service personnel at Saguaro National Monument, phase two of this study may begin as early as December 1, 1986.

Advocating Further Conservation Measures

As Dr. Breunig commented in his message to members at the Garden's annual meeting, our conservation efforts will have failed if the only place an endangered species survives is on one of the Garden's trails. In this spirit, we feel it is important for scientists to present their studies to land managers and policy makers if their results suggest that further measures may be required to conserve a species. This spring, three of the DBG staff participated in the Arizona Plant Recovery Team for threatened and endangered plants organized by the Office of Endangered Species. We also continue to update the Arizona Agriculture and Horticulture Commission, the Arizona Native Plant Society, and The Nature Conservancy's Arizona Chapter on our observations about this and other special plant species. Not all biologists agree that *M. thornberi* justifies official U.S. status as a threatened species, or that it requires such legal protection to insure its survival in the wild. We hope that our studies, combined with those of a dozen or so other concerned scientists and resource managers, may eventually shed light on this dilemma. Whatever its legal status, we advocate further conservation and study of this and other endemic plants of the Sonoran Desert. ■

Acknowledgements

Special thanks to Dr. H.E. Bloss for mycorrhizal analyses and for donating inocula for the experiments in progress. We are grateful for the help of volunteers and staff members who assisted in the DBG's salvage efforts, for Center for Plant Conservation support for part of the salvage work, and for the cooperation of Susan Wright, Peggy Olwell, Robert Hall, Peter Bennett and Sue Rutman of various federal agencies concerned with this plant.

Literature Cited

Bloss, H.E. 1985a. Studies of symbiotic microflora and their role in the ecology of desert plants. Desert Plants 7(3): 119-127.

Bloss, H.E. 1985b. Mycorrhizal fungi, a useful tool for nurserymen. American Nurseryman 162(12): 59-64.

McAuliffe, J.R. 1984. Prey refugia and the distributions of two Sonoran Desert cacti. Oecologia 65: 82-85.

Rutman, S. 1985. The distribution of *Mammillaria thornberi* on Saguaro National Monument, Tucson Mountain Unit, Arizona. Contract report on file with the National Park Service, Tucson.

Agave arizonica:

A Perplexing Problem

by Rick DeLameter and Wendy C. Hodgson

A fascinating scientific story is unfolding in the New River Mountains of central Arizona. It appears that two of the more advanced and successful species of agaves, on the northwest border of their distribution, are evolving new forms, perhaps even a new species: *Agave arizonica.* Yet very little is known about this plant's origins, its current status or its future.

Discovered in 1959 by John H. Weber, *A. arizonica* is an elegant plant that forms small rosettes of dark green leaves with mahogany margins. Weber recorded only eleven plant clones, consisting of one to several rosettes, scattered over an area of fifty square miles. (A clone is a plant, or group of plants, produced vegetatively as an offset from a single parent plant. Each is genetically identical to the parent plant.) Plants were removed from several of these clones for propagation and research at the Desert Botanical Garden. One of the plants flowered here in 1968, and the plant was described by Howard S. Gentry and John H. Weber in 1970. Continuing research revealed only a few new clones, and in 1974 *A. arizonica* was nominated for endangered species

A new field study of *A. arizonica* was begun in 1983 by Rick DeLameter, now a research consultant at the Garden. By this time two new clones had been found and the "population" identified earlier appeared to have dwindled to just a few plants. DeLameter's discovery of three new clones prompted a field trip into the New River Mountains in July 1983 with the authors of the species. The purpose of this trip was to observe *A. arizonica* in habitat and evaluate its need for protection. Recommendations were made shortly thereafter, and in May 1984. *A. arizonica* was listed as an endangered species. Later, there was an attempt to have it de-listed because of its presumed hybrid nature. However, letters supporting its current status and the fact that so little is known about this plant prevented the change of status.

By March 1984, ten new clones were recorded in the New River Mountains but only one of J.H. Weber's original clones still existed. All of the plants occurred as randomly scattered individual plant clones within sympatric (overlapping) populations of two other endemic agaves, *Agave toumeyana* (Trel.) ssp. *bella* (Breitung) Gentry and *Agave chrysantha* Peebles. A comparison of morphological characters has shown that *A. arizonica* is intermediate to these two. When considered along with the scarcity of clones and the lack of any real population, these facts seem to

Peggy Olwell, Wendy Hodgson and Rick DeLameter on a field survey for Agave arizonica. *Photo by George H. Huey/Arizona Highways*

A Perplexing Problem

indicate that *A. arizonica* is of recent hybrid origin.

Based on this supposition, other sympatric populations of *A. toumeyana* ssp. *bella* and *A. chrysantha* were surveyed, and three new clones of *A. arizonica* were found among them in the Camp Creek drainage ten miles east of the New River Mountains. Field investigations at the type locality of *A. toumeyana* ssp. *bella* in the Sierra Ancha Mountains (where *A. chrysantha* is also present) resulted in the discovery of two new clones. These are 100 miles disjunct from the New River population.

In 1983, breeding experiments were performed at the Garden with one *A. Toumeyana* ssp. *bella* and three *A. chrysantha*. *Agave chrysantha* pollen was used to fertilize *A. toumeyana* ssp. *bella* flowers. (It is doubtful that the pollen tube of *A. toumeyana* ssp. *bella* could reach the ovary of an *A. chrysantha* flower.) Seed set was low, but viable seed was produced and germinated. Now three years old, these plants have not yet shown adult characteristics.

In January 1984 an *A. arizonica* clone was discovered which had flowered the previous year (DeLameter 10184). One of the offsets showed bud printing on its leaves and it was developing margins characteristic of *A. toumeyana* ssp. *bella*. The parent plant was typical *A. arizonica*.

All of these findings strongly suggest that *A. arizonica* is continually occurring hybrid between *A. chrysantha* and *A. toumeyana* ssp. *bella*. However, many plant species are of hybrid origin. As Pinkava and Baker (1985) state, "Agaves apparently combine hybridity, polyploidy* and vegetative reproduction as their evolutionary strategy."[1] *Agave arizona* is the product of such strategies. The assumed parents are each among the more highly advanced groups in their respective subgenera, which suggests that polyploid populations are to be found. Gentry concludes that *A. chrysantha* "may be a geologically young species which has not yet reached a stable or isolated condition ... it appears to be mixing genes with its neighbors and may even have had its own origins through introgression ..."[2] *Agave toumeyana* ssp. *bella* itself appears to indicate that speciation is active[2] as it shows distinction from the typical species. By freely cloning and freely seeding, it insures a long sexual generation, hence unlimited gene combinations that will favor its ability to adapt to new environments.

Rick DeLameter surveying an Agave arizonica *clone. Photo by George H. Huey/Arizona Highways*

Field investigations over the last several years have shown that *A. arizonica* occurs in greater numbers than had previously been thought. We know for certain of 32 new clones since 1983. Two of these clones strongly suggest a backcross with *A. toumeyana* ssp. *bella*. Three other clones flowered in 1985 but endangered species status prevented us from doing chromosome counts, pollen staining and crossbreeding studies. We still do not know if *A. arizonica* can reproduce itself sexually.

Because there is still so much to be learned about this agave, the Desert Botanical Garden has requested and has received permission from the U.S. Fish and Wildlife Service to study it. Currently, we are engaged in a thorough survey of its known habitat. The clones are being monitored for: (1.) protection from wildlife and livestock; (2.) collection of flower material for chromosome and pollen stainability studies; (3.) crossbreeding different clones of *A. arizonica* to determine if sexual reproduction is possible; (4.) habitat observation; (5.) pollinator observation and (6.) collection of clonal material from vigorous clones for propagation and research.

Chromosome studies in conjunction with a breeding program should help us answer questions about hybridization and polyploid agave populations. It will also provide information about *A. arizonica, A. chrysantha* and *A. toumeyana* ssp. *bella*. Crossbreeding plants of known ploidy levels would provide valuable insights into the effects of polyploidy on plant morphology.

Any study of agaves will necessarily be a long one because of its long sexual generation. The offspring from our studies may not flower for ten to twenty years, so it is essential that such a program has the support of an institution like the Desert Botanical Garden, where we have made a long-term commitment to plant research and conservation.

**Polyploidy: having a chromosome number that is a multiple greater than two of the basic chromosome number.* ■

Literature cited:

1. Pinkava, Donald, and Marc Baker. 1985. Chromosome and hybridization studies of agaves. Desert Plants. 7(2): 93-100.

2. Gentry, Howard S. 1982. *Agaves of Continental North America*. University of Arizona Press, Tucson.

Buying Time For A Threatened Plant

by Victor Gass

Although it is possible, it is highly unlikely that a species becomes endangered overnight. In natural habitats, there is a span of time in which the various factors influencing a plant's survival are working either to push it toward extinction or to provide more favorable environmental conditions for growth and reproduction. When man intercedes with conservation programs, these recovery efforts might be described as "buying time" for the plants so that natural processes can work to their benefit. In this case, the steps in the recovery process have been accomplished through cooperative efforts of the Desert Botanical Garden and the Forest Service, with assistance from other groups as well.

The plant involved in this rescue effort is *Rumex orthoneurus,* a rare perennial herb related to canaigre and dock, and action has been taken by the Forest Service and the Desert Botanical Garden to help the plant through a critical period in its history. Found in only a handful of localities across the state of Arizona, this *Rumex* is considered a species of concern for which there was sufficient information "to support the appropriateness of proposing to list them as (a federally) endangered species." It is, therefore, designated as a federal *Category 1 Species* at the present time.

The Garden has been involved in the operation since 1982. We have also given assistance in the construction of a fenced enclosure at one of the sites. In addition, we plan to teach others the relatively simple techniques we use to grow the plants so that many more plants can be established. For example, a local school district might make this part of its biology program. Students would learn to understand and appreciate the concept of conserving endangered species by participating in a hands-on project with measurable results.

Illustration by Dyan Del Gaudio

These efforts are just a beginning. Progress has been made, but the recovery is not complete. With the development of conservation work programs involving many organizations, the problems can be reduced. We also know that diligence far into the future will be a crucial factor. We must be aware that future pressures both on the plants and their habitat may again put *Rumex orthoneurus* in jeopardy. ■

Grama grass cactus:

by Gary P. Nabhan

THREATENED BY

While it is commonly understood that many cacti are threatened by overcollecting, it is less known that other cacti are instead endangered by cumulative degradation of their native habitats. Land may still *look* wild, but overgrazing, acid rain or other factors can subtly change the prime habitat of rare plant species.

Through a cooperative agreement with the Office of Endangered Species of the U.S. Fish and Wildlife Service, Desert Botanical Garden staff is currently evaluating the effects of land management practices on a rare cactus, *Toumeya papyracantha*. This species is known as the grama grass cactus, because it often grows within the fairy rings of grama grass *(Bouteloua)* or ring muhly *(Muhlenbergia)*. Remarkably, this cactus is camouflaged amidst the curled, pale blades of old grass since its elongated, papery spines look like grass (see photo). By "hiding" in the dead layers of the grama and muhly grass rings, *Toumeya* may escape predation by rodents and other herbivores.

Unfortunately, overgrazing in certain areas of Arizona and New Mexico has

Toumeya papyracantha. *Photo by Gary P. Nabhan*

At the end of a day of field collection, Gary Nabhan checks his field notes.

OVERGRAZING?

Photo by George H. Huey/Arizona Highways

reduced the cover formerly provided by these grasses. Has this decrease in grassy cover triggered the demise of *Toumeya?* Although scattered over an 11 county area, its populations are nowhere sizeable enough for conservationists to be optimistic about its status. There are often less than a dozen plants in 40 acres of grazed habitat.

To further monitor the status of this plant, in August we began to measure the vegetative cover under different range management practices, relating this factor to *Toumeya* population densities and their dependence on certain grass species for cover. We will be evaluating sites where cattle, sheep and wildlife graze; where juniper trees have been mechanically chained as part of shrub control programs; and where an intensive grazing management strategy known as the Savory System is being implemented. Already, we have documented the loss of this species from sites where it had been observed in the past. Hopefully, our results will suggest to government land managers which range manipulation schemes should be avoided in critical habitat areas if this special cactus is to persist in the wild. ■

Toumeya *hides in the dead layers of grama and muhly grass. Photo by Gary P. Nabhan*

THE GARDEN'S GOAL: *by Gary P. Nabhan*

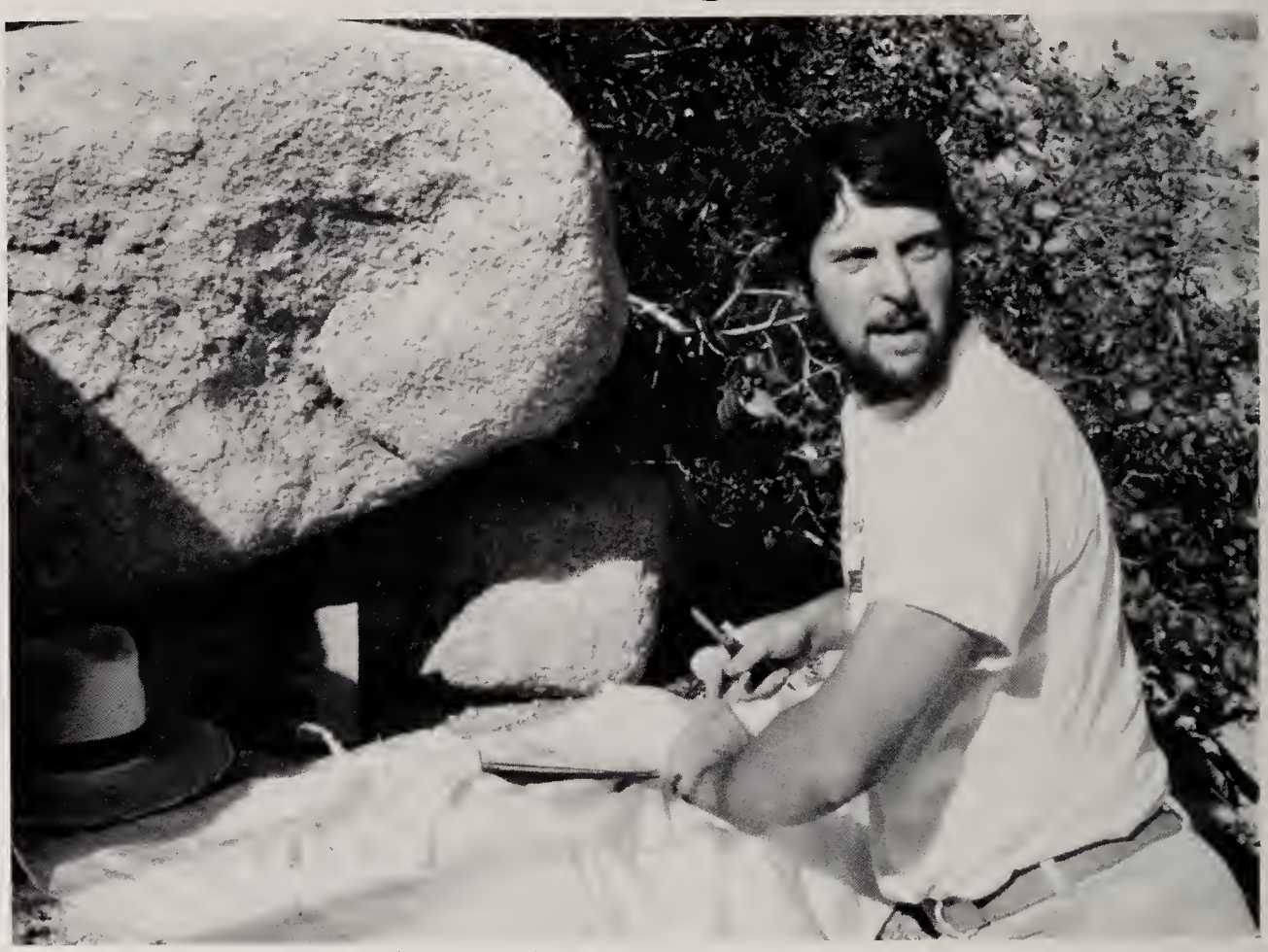
Reversing Desert Degradation

As desert dwellers, many of us are aware of the unique forms of plant life around us — kinds of cacti or wildflowers that we may see within an hour's drive of our homes with one particular kind of vegetation, but that don't exist much farther away than that. Scientists call such restricted distribution of plant species *endemism*. Deserts and semi-deserts probably have the highest percentage of endemic plants in their floras of any vegetation type on the North American continent.

Yet plants which are restricted in their ranges are also particularly vulnerable. An area may rapidly lose entire species should that particular area be devastated by a natural or manmade disturbance. Unfortunately, many areas rich in desert endemics are undergoing drastic environmental change. Our arid zone vegetation is being more rapidly cleared, contaminated and degraded than that of any other ecological zone in the world. Every hour, an area of this planet's arid and semi-arid lands 50 times the size of the Desert Botanical Garden's 150 acres is being reduced to zero productivity.

When desert land is driven over, over-grazed or overharvested, rare plants are often the first species eliminated. Estimates vary, but more than 20% of the earth's vegetation is directly threatened by desertification. In Arizona, a conservative estimate of 100 plants are considered threatened or endangered as species. The gene pools of many other plant resources are being "drained" within our state.

Ironically, some of the very plants that could eventually restore degraded lands back to a productive condition have virtually disappeared in recent years. In the ten U.S. and Mexican states along the International Boundary, 156 genera of useful plants are each represented by at least one species that is currently at risk. Of wild relatives of crops that may eventually be utilized by plant breeders, 10-15% of the 500 species growing in the U.S./Mexico borderlands are threatened or endangered.



Photos by George H. Huey/Arizona Highways.

Improved Techniques for Propagating Plants at Risk

What is the Garden doing to counter these trends? First, consider our propagation of plants at risk, in part through our collaboration with the Center for Plant Conservation. Victor Gass, our curator of living collections, has determined that the Garden currently holds 32 imperiled species of plants as live, on-the-grounds collections, and 17 species as seeds. Only six of these are currently protected by the federal government as officially listed threatened and endangered species, but our involvement in legal plant recovery team efforts may double this number in the coming years.

We are also working to improve our propagation, care and long-term preservation of genetic variation for the threatened plant populations on our grounds. Over the Garden's 48 year history, we have had a cumulative total of 64 threatened and endangered species, double the current number of live plant collections currently exhibited. What happened to the others, and how can we prevent such attrition in the future? On October 15, we launched a renewed effort at conserving pollen, seed and live plants for genetic maintenance of threatened plants. Drawing upon the experience of nationally-recognized experts in this field, 24 participants from our Garden staff, from nearby museums and arboreta, and from the Office of Endangered Species discussed the practicalities of better managing endangered plant populations under propagation. This practicum was funded by the Institute of Museum Services, as part of a conservation grant which was recently awarded to the Garden.

The topics covered during the October 15 workshop ranged from methods and ethics of field-collecting rare species, to population genetics, to new technologies aiding in long term frozen storage of pollen and seeds. Guest speakers included Dr. Harold Koopowitz, co-author of *Plant Extinctions,* and director of the University of California/Irvine Arboretum, and Dr. Thomas Elias, co-editor of *Extinction*

is Forever, and director of the Rancho Santa Ana Botanical Garden.

New Skills & Technology

In addition to new skills obtained at the workshop, Desert Botanical Garden staff members are ready to utilize new facilities and materials for more sophisticated management of seed and pollen of threatened plants. Instead of storing this germplasm at room temperature and humidity levels which rapidly reduce their longevity, we are implementing low humidity frozen storage of newly-collected materials as soon as they arrive at the Garden.

By drying seed down with silica gel dessicant and freezing samples in sealed humidity-excluding poly-foil envelopes, we can increase the longevity of endangered plant germplasm tenfold. We will be storing these labeled envelopes at -10° Fahrenheit for back-up, long term maintenance, and at just below 0° Fahrenheit for accessions to be planted within the coming year. Pollen of species such as the night-blooming cereus will also be dried and frozen, to be thawed out whenever propagators need to hand-pollinate plants flowering on the garden grounds. By making what is known as "family crosses" between collections from the same original field population, we can better conserve within-population variation.

We will also be upgrading our monitoring of temperature, soils and moisture for endangered species kept in our greenhouses and lath-covered nursery areas. Clayton Newberry, new assistant propagator, will help Patrick Quirk and Victor Gass with this monitoring effort, as well as that aimed at plants already located on our grounds. The Garden is grateful for the support from the Institute of Museum Services and the Center for Plant Conservation that makes it possible to devote additional care to the special plants in our collections.

International Cooperation

Finally, we are exploring ways to reduce pressures on threatened plants and, possibly, to increase their numbers in the wild and in cultivation. Through a request from the U.S. Embassy in Mexico, we are working in a consulting role for the next three years with several botanical gardens and desert research institutes in Mexico to explore ways to propagate and develop threatened plant resources for restoring degraded desert areas. This includes attempts to propagate endangered cacti that are now being over-collected in the wild, to reforest cleared areas with useful plants now rarely found in certain areas, and to diversify small-scale agriculture with native plant resources. Two researchers from the Autonomous University of Tamaulipas, Guadalupe Malda Barrera and Humberto Susan, not only participated in the October 15 workshop, but underwent additional "training" regarding conservation of threatened plant resources at the Garden in October. Malda is the manager of the University's new botanic garden, which is active in endangered species work, and biologist Susan is director of the Rancho del Cielo Biosphere Reserve that protects desert and cloud forest ecosystems in Tamaulipas. Through exchanges with their programs and others, we hope to encourage integrated plant conservation efforts in developing regions.

A complement to this work in Mexico will be further enrichment of Dr. Gentry's experimental nursery of economic plants of desert zones with additional germplasm collections. We will emphasize plants suitable for use in minimum-irrigation desert farming and revegetation projects. Our ultimate goal is to see desert areas replenished with a diversity of useful native plants, rather than being further degraded. ■

This premier color issue of *Agave* was made possible by a generous gift from **Chase Bank of Arizona.**

Photographer George H. Huey accompanied Gary Nabhan on a recent field trip to gather information for an article on plant conservation that will appear in an upcoming issue of *Arizona Highways.*

DESERT
BOTANICAL
GARDEN

1201 N. Galvin Parkway
Phoenix, AZ 85008